Observed HR diagrams and stellar evolution: the interplay between observational constraints and theory
ASP Conference Series, Vol. ???, 2001
Thibault Lejeune and João Fernandes, eds.

Atmospheric parameters for non-interacting eclipsing binaries: preliminary results from synthetic photometry

E. Lastennet, F. Cuisinier

Depto. de Astronomia, UFRJ, Rio de Janeiro, Brazil

T. Lejeune

Observatório Astronómico, Coimbra, Portugal

Abstract. Double-lined spectroscopic binaries which are also eclipsing provide the most accurate stellar data, and are consequently of first importance to improve stellar evolution modelling. While the mass and radius of each component of detached eclipsing binaries (EBs) can be accurately known, their temperature ($T_{\rm eff}$) and chemical composition ([Fe/H]) are still uncertain. To contribute to overcome these difficulties, we present metallicity-dependent $T_{\rm eff}$ determinations of 11 EBs (22 individual stars) from Strömgren synthetic photometry. Inconsistencies suggesting new photometric observations are discussed. Moreover, by exploring the best χ^2-fits to the photometric data, we have re-derived their reddening.

1. Introduction

A small sample of detached EBs provide accurate individual mass and radius (Andersen 1991). As stressed by many authors (see e.g. Clausen 1993), [Fe/H] is the main remaining uncertainty of these stars, and their $T_{\rm eff}$ are inhomogeneously determined (Lastennet et al. 1999, LLWB99). The determination of these two last parameters is motivating because the knowledge of all possible stellar parameters for such stars is the basis of the modelling of the global physical properties and evolution of star clusters or galaxies. In this context, the present work follows LLWB99 to determine metallicity-dependent $T_{\rm eff}$s of non-interacting EBs from Strömgren photometry.

2. Sample of eclipsing binaries and method

Table 1 gives the individual Strömgren photometry and surface gravity we used for our working sample. This sample covers a wide mass range, from 1.198 (UX Men B) to 27.27 $M_\odot$ (V3903 Sgr A). To be consistent with the LLWB99 work we only kept EBs with (b−y), m_1 and c_1 data. The other commonly used Strömgren index β - not affected by interstellar reddening or the distance of the stars - would provide another observational constraint, however we decided to exclude it from our study. The reason is twofold: first, determinations for both components of

a system are not always available (mainly due to the narrow bandpass of the H_β filters), and secondly, the synthetic β index from the BaSeL models is not reliable because - by construction - the resolution of flux distributions is 10-20 Å (see Lastennet 1998 for a proposed correction).

Photometric errors While only binaries with photometric errors were considered in LLWB99, here we consider systems with no photometric errors published, except for HS Hya and V906 Sco. For the case were these errors are supplied[1], the mean values are $\sigma_{(b-y)}$=0.013, $\sigma_{(m1)}$=0.022 and $\sigma_{(c1)}$=0.027. We adopt these mean errors for the systems reported with no photometric errors in Tab. 1.

Table 1. Basic data from Jordi et al. 1997 (except HS Hya and V760 Sco) for the sample. Reddening is given in the two last columns.

System	(b−y)	m_1	c_1	log g	E(b−y)†	E(b−y)
V539 Ara	−.038	.088	.249	3.926±0.017	0.050	0.051$^{(1)}$
	−.032	.090	.285	4.096±0.022	0.050	0.053$^{(1)}$
QX Car	−.072	.087	.036	4.140±0.020	0.032	0.036$^{(2)}$
	−.072	.092	.076	4.151±0.021	0.029	
SZ Cen	.188	.210	.983	3.486±0.008	0.000	0.058$^{(3)}$
	.166	.188	1.019	3.677±0.007	0.051	
χ^2 Hya	−.02	.11	.83	3.712±0.015	0.013	0.012$^{(4)}$
	−.01	.11	.84	4.188±0.019	0.025	
UX Men	.359	.161	.371	4.272±0.009	0.070	0.02±0.02$^{(5)}$
	.368	.174	.367	4.306±0.009	0.070	
V760 Sco	.155	.029	.373	4.177±0.021	0.230	0.24$^{(6)}$
	.162	.027	.410	4.259±0.019	0.240	
V1647 Sgr	.022	.163	1.018	4.253±0.012	0.029	0.029$^{(7)}$
	.057	.182	0.979	4.289±0.012	0.030	0.030$^{(7)}$
V3903 Sgr	.184	.006	−.114	4.058±0.016	0.310	0.32$^{(8)}$
	.191	.001	−.076	4.143±0.013	0.310	
CV Vel	−.067	.100	.269	4.000±0.008	0.013	0.030$^{(9)}$
	−.064	.097	.277	4.023±0.008	0.018	
HS Hya	.289±.007	.144±.007	.421±.007	4.3259±0.0056	0.000	−0.004$^{(10)}$
	.302±.007	.156±.008	.374±.007	4.3539±0.0057	0.000	
V906 Sco	.044±.003	.126±.004	1.023±.005	3.656±0.012	0.070	0.059$^{(11)}$
	.063±.002	.094±.002	1.183±.002	3.858±0.013	0.093	

† this work. $^{(1)}$ Clausen (1996, A&A, 308, 151); $^{(2)}$ Andersen et al. (1983, A&A, 121, 271); $^{(3)}$ Grønbech et al. (1977, A&A, 55, 401); $^{(4)}$ Clausen & Nordström (1978, A&A, 67, 15); $^{(5)}$ Andersen et al. (1989, A&A, 211, 346); $^{(6)}$ Andersen et al. (1985, A&A, 151, 329); $^{(7)}$ Andersen & Giménez (1985, A&A, 145, 206); $^{(8)}$ Vaz et al. (1997, A&A, 327, 1094); $^{(9)}$ Clausen & Grønbech (1977, A&A, 58, 131); $^{(10)}$ Torres et al. (1997); $^{(11)}$ Alencar et al. (1997, A&A, 326, 709).

Method We apply a χ^2-minimization method on the BaSeL models (Lejeune et al. 1998, see also Lastennet, Lejeune & Cuisinier, these proceedings) to derive the $T_{\rm eff}$ and [Fe/H] values matching simultaneously the observed Strömgren photometry, the surface gravity (log g) being fixed to its accurately determined value (see LLWB99 for details).

[1] i.e. HS Hya, V906 Sco and the binaries listed in LLWB99, excluding IQ Per and YZ Cas because their B components are much fainter than the A components, implying large errors in their colour indices measurements

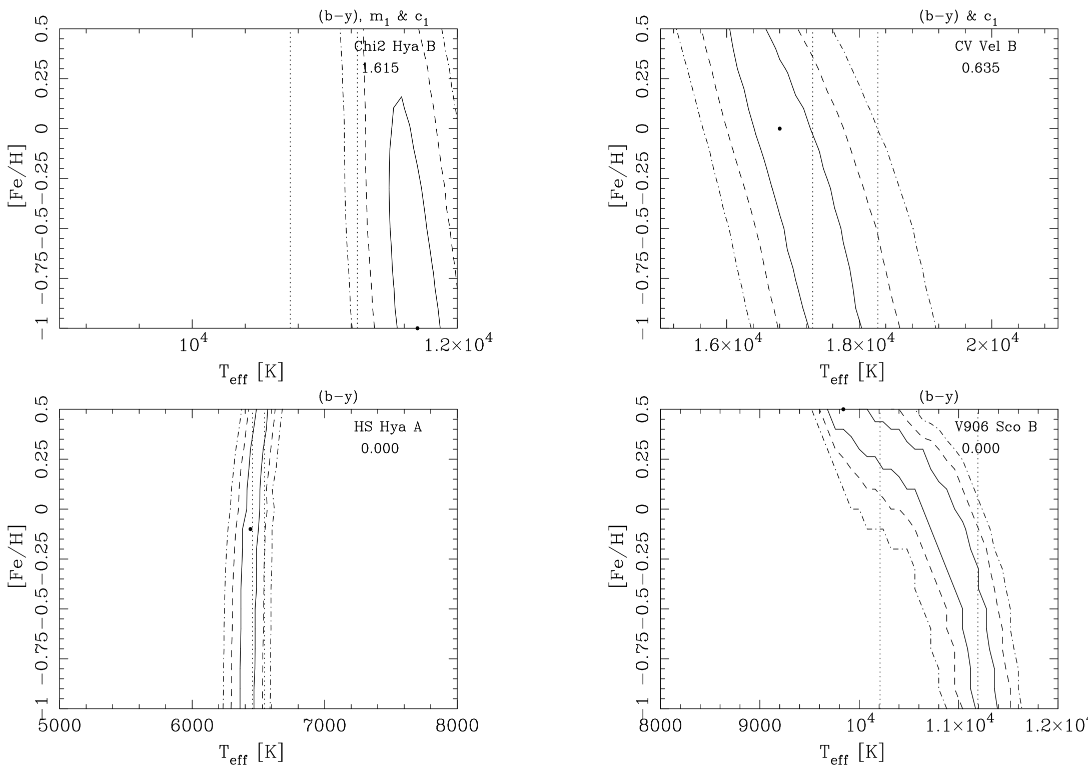

Figure 1. Examples of (T_{eff}-[Fe/H]) solutions matching b−y, m_1 and c_1 (upper left) and b−y and c_1 (upper right). T_{eff} determination from the b−y index alone: HS Hya A and V906 Sco B (lower panels). Previous determinations are shown as vertical lines (references in Ribas et al. 2000).

3. Discussion

Results derived from (b−y), m_1 and c_1 The surprising result is that BaSeL is unable to match simultaneously b−y, m_1 and c_1, independently of the value of reddening adopted. All the χ^2-scores are bad (> 10), except for both components of the system χ^2 Hya: its primary component gives a very good agreement with previous T_{eff} determinations, but we favour a T_{eff} larger by $\sim$ 700K for χ^2 Hya B (see Fig. 1). Of course, the χ^2-scores are related to the assumed photometric errors, so largest errors should give better (i.e. smaller) χ^2 values. The 2 binaries with published photometric errors (HS Hya and V760 Sco) give bad fit as well. Further study is needed, as well as more information on the observed Strömgren data before definitive conclusion. Reasons for these discrepancies could be that: **1)** the BaSeL models are not fit to predict Strömgren indices. This explanation is possible because some problems due to the m_1 and c_1 indices were detected for F-type stars with the BaSeL Strömgren synthetic photometry (Lastennet et al. 2001). However, only UX Men and HS Hya contain F-type stars, so this cannot be a general explanation for our sample. Moreover, only $\sim$17% (7 over 40) of the stars studied by LLWB99 presented a similar bad fit (and this was not correlated with a particular T_{eff} range) against $\sim$91% (20 over 22) in

the present sample. Another convincing point against unreliable results from the BaSeL Strömgren synthetic photometry is that among the 9 F-type stars studied by LLWB99, only 2 stars show bad fits. **2)** the differential reddening in the direction of these stars is strongly different from the standard values that we adopt. A comparison between the reddening found in the literature and derived from BaSeL (Tab. 1) show a good agreement, except for SZ Cen A but even in this case the disagreement is only of 0.058 mag. **3)** the choice of b−y, m_1 and c_1 is not critical enough for the purpose of this work. When it is true that b−y becomes increasingly insensitive to $T_{\rm eff}$ for the hotter stars (for $(b-y)_0<0$), it appears that even in this defavorable range BaSeL is able to predict good results (e.g. EM Car or CW Cep in LLWB99). It is worth noting that even bad fits give results in agreement with previous studies. Another unexpected (because badly fitted) but interesting result is obtained for QX Car: we predict a rich metallicity ([Fe/H]>0.30 (0.15) from the primary (secondary)) which is in agreement with previous estimates: Lastennet (1998) (Z=0.04 from 2 different stellar models, i.e. [Fe/H]∼0.39), and the extrapolated result of Ribas et al. (2000) (Z=0.035, i.e. [Fe/H]∼0.32). **4)** the observed colors of these stars are in some way erroneous and should be carefully re-determined from new photometric observations.

$T_{\rm eff}$ and/or [Fe/H] from 1 or 2 photometric constraints When bad fits were obtained using all the photometric data (3 colours), LLWB99 considered the solutions derived from the combination of 2 colours. In this case, the results match - all with success - (b−y) and c_1 simultaneously (e.g. Fig. 1, right upper panel). A comparison of $T_{\rm eff}$(BaSeL) with previous studies shows a general good agreement, but $T_{\rm eff}$(BaSeL) are slightly but systematically lower. Unfortunately, few information is derived for [Fe/H], all the range considered being virtually possible inside the 1-σ contours. Finally, we show in Fig. 1 (lower panels) the solutions obtained from the b−y index alone for the 2 only systems with photometric errors. The $T_{\rm eff}$ determinations show a perfect agreement with previous works. A precise spectroscopic determination of the HS Hya metallicity is needed but if one assumes the value of [Fe/H]= −0.17 (Torres et al., 1997), then we predict $T_{\rm eff}$ in the range 6380-6440 K (primary) and 6320-6380 K (secondary). These $T_{\rm eff}$s are slightly lower than the results of Torres et al.: 6450-6550 (primary) and 6350-6450 K (secondary).

References

Andersen J., 1991, ARA&A, 3, 91
Clausen J.V., 1993, ASP Conf. Series 40, 177
Clausen J.V., Grønbech B., 1977, A&A, 58, 131
Jordi C., Ribas I., Torra J., Giménez A., 1997, A&A, 326, 1044
Lastennet E., 1998, Ph-D thesis, Univ. L. Pasteur, Obs. de Strasbourg, France
Lastennet E., Lejeune Th., Westera P., Buser R., 1999, A&A, 341, 857, (LLWB99)
Lastennet E., Lignières F., Buser R., et al. 2001, A&A, 365, 535
Lejeune Th., Cuisinier F., Buser R., 1998, A&AS, 130, 65
Ribas I., Jordi C., Torra J., Giménez A., 2000, MNRAS, 313, 99
Torres G., et al. 1997, AJ, 114, 2764